Pneumonia Detection from Chest X-Ray Images

A Project Report
Submitted in fulfillment of the requirements for the award of
The Certificate for

Internship Program 2019

By

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ABSTRACT

With the high rise in popularity of neural networks, researchers and engineers have been able to find many world-changing applications for computer vision. Today, I want to show you an example of this. By acquiring a labeled dataset of chest x-ray scans for pneumonia, I was able to rapidly build and prototype an artificial intelligence model that identified pneumonia cases with 96% accuracy. (for train_data)

Computer Vision & Convolutional Neural Networks

CNNs are very similar to the traditional feed-forward networks which have come to define deep learning, except that they implement a mathematical operation known as a convolution. Compared to traditional neural networks, they are a lot more efficient at processing image data. By applying convolutions, we can we can be much more efficient with these operations.

Organizing our X-Ray Scans

Thanks to Kaggle, I was able to obtain this dataset for pneumonia x-ray scans, which already came labeled! There was one folder named “Normal Scans” and another “Pneumonia Scans”. Detecting pneumonia in an x-ray scan is a simple binary classification problem: either we detect pneumonia, or we don’t. Did I give you a good hint with binary?

Building Our Model

A great prototyping library/tool is Keras. Keras is a high-level API which lets you build neural networks quickly, without having to worry too much about their intricacies. Keras uses a more complicated framework on the back-end which you get to define. For this Pneumonia detection example, I used Keras with a Tensorflow backend. Here we also install pillow library for loading, modifying and saving images.

Training and Testing the Network

Let’s train the network. Fundamentally speaking, the process we are automating is very simple. The accuracy achieved on train_data is 96%.

CONTENTS

Problem Statement: To detect Pneumonia clouds in scanned **Chest X-Rays** of pediatric patients.

1. Introduction

Finding ways to automate diagnostics from medical images, has continuously been one of the most interesting areas of software development. This model presents an approach for detecting the presence of pneumonia clouds in chest X-rays by using Image processing techniques. For this, we have worked on a dataset containing Chest X-ray images pertaining to Normal and Pneumonia infected patients. The task has been performed using Python and keras with Tensorflow as background because they are free, open source tools and can be used by all, without any legality issues or cost implication.

Artificial Intelligence

Artificial intelligence (AI) is the branch of computer science which aims to create intelligence machines. Artificial Intelligence (AI) is the study of how computer systems can simulate intelligent processes such as learning, reasoning, and understanding symbolic information in context.
It is simply a technique which enables computer to mimic human behavior.

Neural Networks

A **neural network** is a network or circuit of neurons, or in a modern sense, an artificial neural network, composed of artificial neurons or nodes for solving Artificial Intelligence (AI) problems.

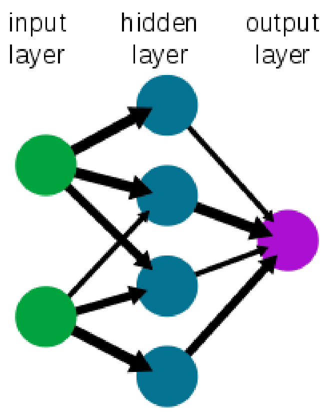


Fig 1.1 A Simple Neural Network

Convolutional Neural Networks

A **Convolutional Neural Network** (**CNN**, or **ConvNet**) is a class of deep neural networks, most commonly applied to analyzing visual imagery.
They have applications in image and video recognition, recommender systems, image classification, medical image analysis, and natural language processing.

Building Blocks

- Convolution Layer
- Pooling Layer
- RELU Layer
- Full Connection

2. Dataset Details

Dataset Name	:	chest-xray-pneumonia
Dataset source	:	https://www.kaggle.com/paultimothymooney/chest-xray-pneumonia

Chest X-ray images of pediatric patients of one to five years old were selected as part of patients' routine clinical care and grouped in this dataset.
The Dataset is organized into three folders (train, test and val) and contains two subfolders (Pneumonia/Normal) for each image category.

Number of Classes	:	2
Number of Images	:	

Training	:	5216			
			Normal	:	1341
			Pneumonia	:	3875
Testing	:	624			
			Normal	:	234
			Pneumonia	:	390
Validation	:	16			
			Normal	:	08
			Pneumonia	:	08

In total there are 5856 X-Ray images (JPEG) under 2 categories (Pneumonia/Normal).

3. Libraries

Keras

Keras is an open-source neural-network library written in Python. It is capable of running on top of TensorFlow, Microsoft Cognitive Toolkit, Theano, or PlaidML.

Designed to enable fast experimentation with deep neural networks, it focuses on being user-friendly, modular, and extensible.

TensorFlow

TensorFlow is a free and open-source software library for dataflow and differentiable programming across a range of tasks. It is a symbolic math library, and is also used for machine learning applications such as neural networks.

Fig 3.1 TensorFlow Logo

Pillow

Python Imaging Library (abbreviated as **PIL**) (in newer versions known as Pillow) is a free library for the Python programming language that adds support for opening, manipulating, and saving many different image file formats. It is available for Windows, Mac OS X and Linux.

Matplotlib

Matplotlib is a plotting library for the Python programming language and its numerical mathematics extension NumPy. It provides an object-oriented API for embedding plots into applications using general-purpose GUI toolkits like Tkinter, wxPython, Qt, or GTK+.

Matplotlib was originally written by John D. Hunter, has an active development community, and is distributed under a BSD-style license.

4. Functions

image_data_format()

The "backend" parameter should either be "tensorflow", "cntk", or "theano". When switching the backend, make sure to switch the "image_data_format" parameter too. For "tensorflow "or "cntk" backends, it should be "**channels_last**". For "theano", it should be "**channels_first**".

```
"image_data_format": "channels_first",
  "backend": "theano"
```

```
  "image_data_format": "channels_last",
  "backend": "tensorflow"
```

ImageDataGenerator()

Generate batches of tensor image data with real-time data augmentation. The data will be looped over (in batches) i.e it behaves like an iterator. It has a special keyword yield**,** which is similar to **return** as it returns some value. When the generator is called, it will return some value and save the state. Next time when we call the generator again, it will resume from the saved state, and return the next set of values just like an iterator.

Thus using the advantage of generator, we can iterate over each (or batches of) image(s) in the large data-set and train our neural net quite easily.

flow_from_directory()

The ImageDataGenerator class has three methods flow(),flow_from_directory() and flow_from_dataframe() to read the images from a big numpy array and folders containing images.

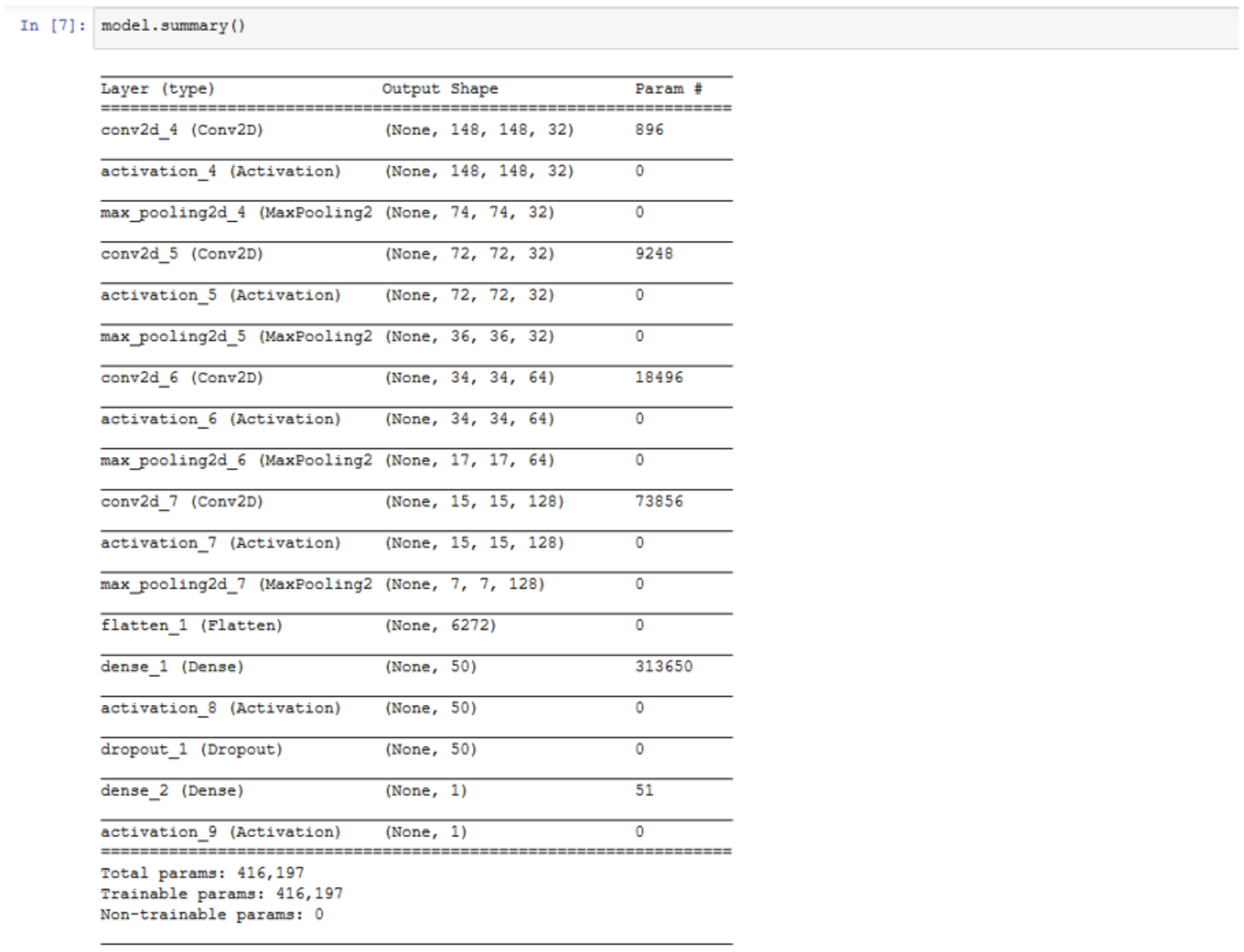
The **flow_from_directory()** expects at least one directory under the given directory path.

fit_generator()

In **fit_generator**() , you don't pass the x and y directly, instead they come from a generator.
As it is written in keras documentation, generator is used when you want to avoid duplicate data when using multiprocessing. This is for practical purpose, when you have large dataset.

keras' fit_generator() function is used if

- Real-world datasets are often too large to fit into memory.
- They also tend to be challenging, requiring us to perform data augmentation to avoid overfitting and increase the ability of our model to generalize.



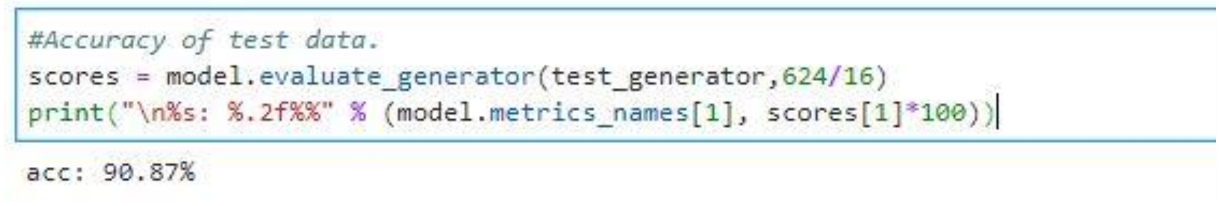
```
In [7]: model.summary()

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_4 (Conv2D)            (None, 148, 148, 32)      896
_________________________________________________________________
activation_4 (Activation)    (None, 148, 148, 32)      0
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 74, 74, 32)        0
_________________________________________________________________
conv2d_5 (Conv2D)            (None, 72, 72, 32)        9248
_________________________________________________________________
activation_5 (Activation)    (None, 72, 72, 32)        0
_________________________________________________________________
max_pooling2d_5 (MaxPooling2 (None, 36, 36, 32)        0
_________________________________________________________________
conv2d_6 (Conv2D)            (None, 34, 34, 64)        18496
_________________________________________________________________
activation_6 (Activation)    (None, 34, 34, 64)        0
_________________________________________________________________
max_pooling2d_6 (MaxPooling2 (None, 17, 17, 64)        0
_________________________________________________________________
conv2d_7 (Conv2D)            (None, 15, 15, 128)       73856
_________________________________________________________________
activation_7 (Activation)    (None, 15, 15, 128)       0
_________________________________________________________________
max_pooling2d_7 (MaxPooling2 (None, 7, 7, 128)         0
_________________________________________________________________
flatten_1 (Flatten)          (None, 6272)              0
_________________________________________________________________
dense_1 (Dense)              (None, 50)                313650
_________________________________________________________________
activation_8 (Activation)    (None, 50)                0
_________________________________________________________________
dropout_1 (Dropout)          (None, 50)                0
_________________________________________________________________
dense_2 (Dense)              (None, 1)                 51
_________________________________________________________________
activation_9 (Activation)    (None, 1)                 0
=================================================================
Total params: 416,197
Trainable params: 416,197
Non-trainable params: 0
_________________________________________________________________
```

Fig 4.1 Convolution and Pooling

evaluate_generator()

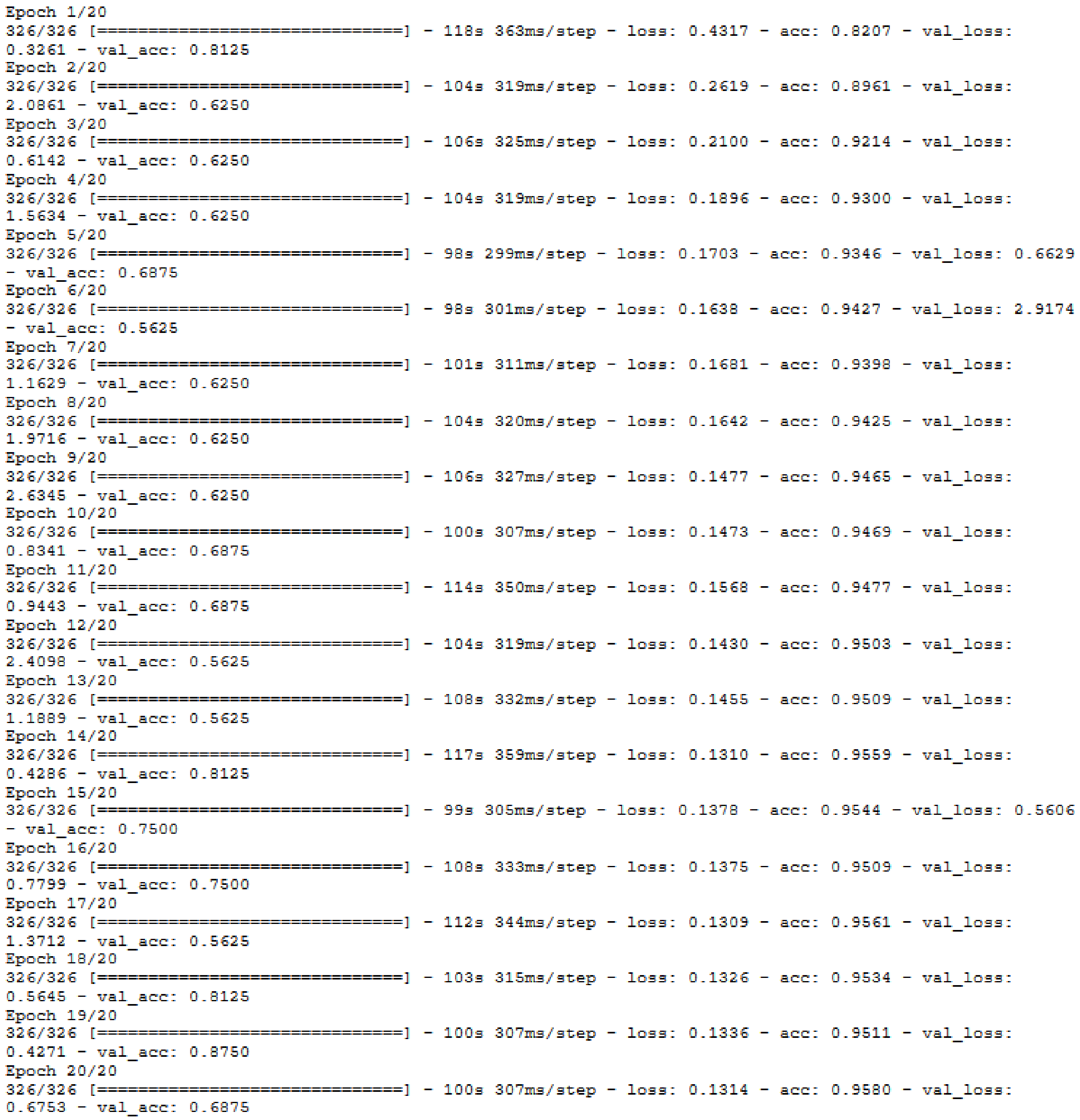
Evaluates the model on a data generator.



```
#Accuracy of test data.
scores = model.evaluate_generator(test_generator,624/16)
print("\n%s: %.2f%%" % (model.metrics_names[1], scores[1]*100))

acc: 90.87%
```

Fig 4.2 evaluate_generator()



```
Epoch 1/20
326/326 [==============================] - 118s 363ms/step - loss: 0.4317 - acc: 0.8207 - val_loss:
0.3261 - val_acc: 0.8125
Epoch 2/20
326/326 [==============================] - 104s 319ms/step - loss: 0.2619 - acc: 0.8961 - val_loss:
2.0861 - val_acc: 0.6250
Epoch 3/20
326/326 [==============================] - 106s 325ms/step - loss: 0.2100 - acc: 0.9214 - val_loss:
0.6142 - val_acc: 0.6250
Epoch 4/20
326/326 [==============================] - 104s 319ms/step - loss: 0.1896 - acc: 0.9300 - val_loss:
1.5634 - val_acc: 0.6250
Epoch 5/20
326/326 [==============================] - 98s 299ms/step - loss: 0.1703 - acc: 0.9346 - val_loss: 0.6629
- val_acc: 0.6875
Epoch 6/20
326/326 [==============================] - 98s 301ms/step - loss: 0.1638 - acc: 0.9427 - val_loss: 2.9174
- val_acc: 0.5625
Epoch 7/20
326/326 [==============================] - 101s 311ms/step - loss: 0.1681 - acc: 0.9398 - val_loss:
1.1629 - val_acc: 0.6250
Epoch 8/20
326/326 [==============================] - 104s 320ms/step - loss: 0.1642 - acc: 0.9425 - val_loss:
1.9716 - val_acc: 0.6250
Epoch 9/20
326/326 [==============================] - 106s 327ms/step - loss: 0.1477 - acc: 0.9465 - val_loss:
2.6345 - val_acc: 0.6250
Epoch 10/20
326/326 [==============================] - 100s 307ms/step - loss: 0.1473 - acc: 0.9469 - val_loss:
0.8341 - val_acc: 0.6875
Epoch 11/20
326/326 [==============================] - 114s 350ms/step - loss: 0.1568 - acc: 0.9477 - val_loss:
0.9443 - val_acc: 0.6875
Epoch 12/20
326/326 [==============================] - 104s 319ms/step - loss: 0.1430 - acc: 0.9503 - val_loss:
2.4098 - val_acc: 0.5625
Epoch 13/20
326/326 [==============================] - 108s 332ms/step - loss: 0.1455 - acc: 0.9509 - val_loss:
1.1889 - val_acc: 0.5625
Epoch 14/20
326/326 [==============================] - 117s 359ms/step - loss: 0.1310 - acc: 0.9559 - val_loss:
0.4286 - val_acc: 0.8125
Epoch 15/20
326/326 [==============================] - 99s 305ms/step - loss: 0.1378 - acc: 0.9544 - val_loss: 0.5606
- val_acc: 0.7500
Epoch 16/20
326/326 [==============================] - 108s 333ms/step - loss: 0.1375 - acc: 0.9509 - val_loss:
0.7799 - val_acc: 0.7500
Epoch 17/20
326/326 [==============================] - 112s 344ms/step - loss: 0.1309 - acc: 0.9561 - val_loss:
1.3712 - val_acc: 0.5625
Epoch 18/20
326/326 [==============================] - 103s 315ms/step - loss: 0.1326 - acc: 0.9534 - val_loss:
0.5645 - val_acc: 0.8125
Epoch 19/20
326/326 [==============================] - 100s 307ms/step - loss: 0.1336 - acc: 0.9511 - val_loss:
0.4271 - val_acc: 0.8750
Epoch 20/20
326/326 [==============================] - 100s 307ms/step - loss: 0.1314 - acc: 0.9580 - val_loss:
0.6753 - val_acc: 0.6875
```

Fig 4.3 Epochs

Output

• Accuracy for train_data	:	95.80
• Loss for train_data	:	13.14
Accuracy of Test_Data	:	90.31

Conclusion

Thus a model was built for detecting pneumonia from scanned X-ray images by using CNN with an accuracy of 95% (on train_data) and an accuracy of 90% (on test_data) approximately.

Further Enhancements:

- We can compile the model at more number of epochs.
- Hyper-parameter Tuning(There are a lot of parameters that we can play with).
- Use of much more deeper architectures.

References

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Appendices

Image processing

Image processing is a method to perform some operations on an **image**, in order to get an enhanced image or to extract some useful information from it. It is a type of signal processing in which input is an image and output may be image or characteristics/features associated with that image.

Neuron

A **neuron** (also called nerve cell) is a cell that carries electrical impulses. Neurons are the basic units of the nervous system. Every neuron is made of a cell body (also called a soma), dendrites and an axon. Dendrites and axons are nerve fibers

Theano

Theano is a Python library and optimizing compiler for manipulating and evaluating mathematical expressions, especially matrix-valued ones.